Cloud Aerosol Discrimination (CAD) in CALIOP version 4 level 2 data – CAD everywhere!

J. Kar[1], Z. Liu[1], M. A. Vaughan[2], J. L. Tackett[1], S. Zeng[1], B. Getzewich[1], K. P. Lee[1], P. L. Lucker[1], B. Magill[1], A. H. Omar[2], C. R. Trepte[2], D. M. Winker[2]

[1] Science Systems and Applications Inc., Hampton, VA, USA
[2] NASA Langley Research Center, Hampton, VA, USA

INTRODUCTION

In the CALIOP retrieval algorithm, detection of a layer from the backscatter measurements is followed by its classification as a "cloud" or "aerosol", currently using 5-dimensional Probability Density Functions (PDF) which are derived using a training set (Liu et al., 2009). The five dimensions are the mean attenuated backscatter at 532 nm, the layer integrated total attenuated color ratio, the mid layer altitude, integrated volume depolarization ratio and latitude. With the release of the new version 4 level 1 data, it became necessary to optimize the CAD algorithm for the version 4 level 2 data. Accordingly, a new set of CAD PDFs was generated and has subsequently been used in test versions of new level 2 data. A new element in version 4 is to extend the algorithm to stratospheric altitudes, where volcanic layers as well as occasional cloud and smoke layers are observed. Yet another important application of the new CAD algorithm relates to the layers detected at the single shot (333 m) resolution, even though these layers were not used in the training sets for building the PDFs. These are dense layers often seen embedded within large scale dust, smoke and marine layers and are detected using the 1064 nm backscatter measurements. In the past, these layers were classified as clouds by default and removed before averaging over the weaker signals (Vaughan et al., 2009). We present characterization and performance of the new CAD algorithm for all of these components, i.e., in the troposphere, stratosphere as well as for the single shot layers. Only nighttime data are used for the analyses presented here.

OVERALL CHANGES FROM VERSION 3 TO VERSION 4

Most samples in V4 classified with high confidence (|CAD|> 70), but the fraction with low/medium scores (−40<CAD<40) has also increased.
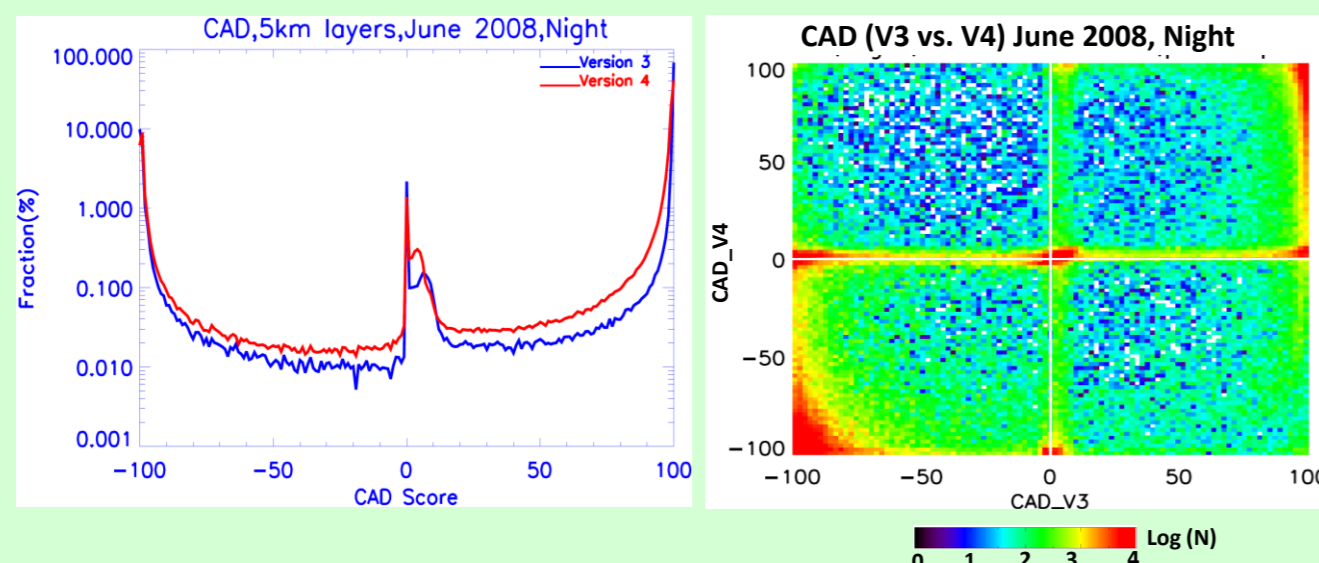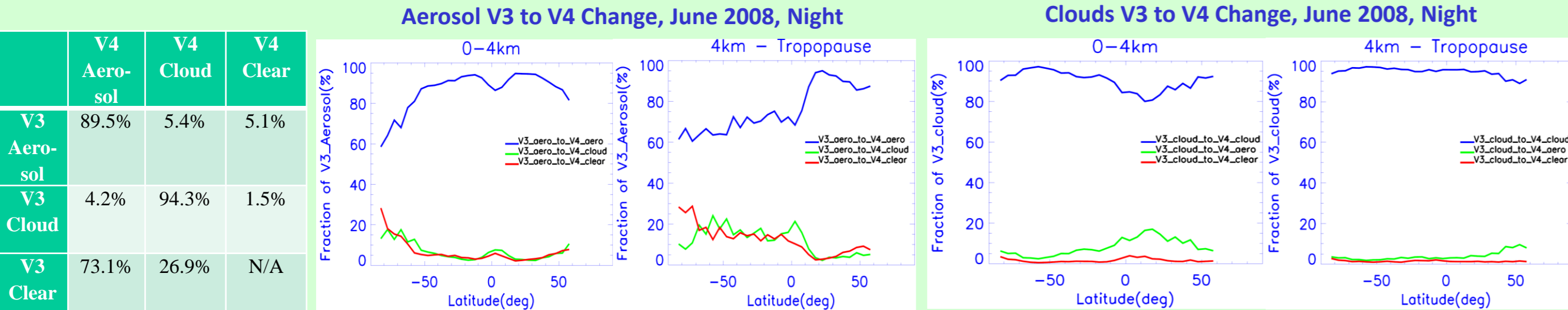
Most of the high confidence samples in V3 are also classified as the same type (cloud or aerosol) in V4 with similar high confidence, but some features with high CAD scores in V3 have lower CAD scores in V4.
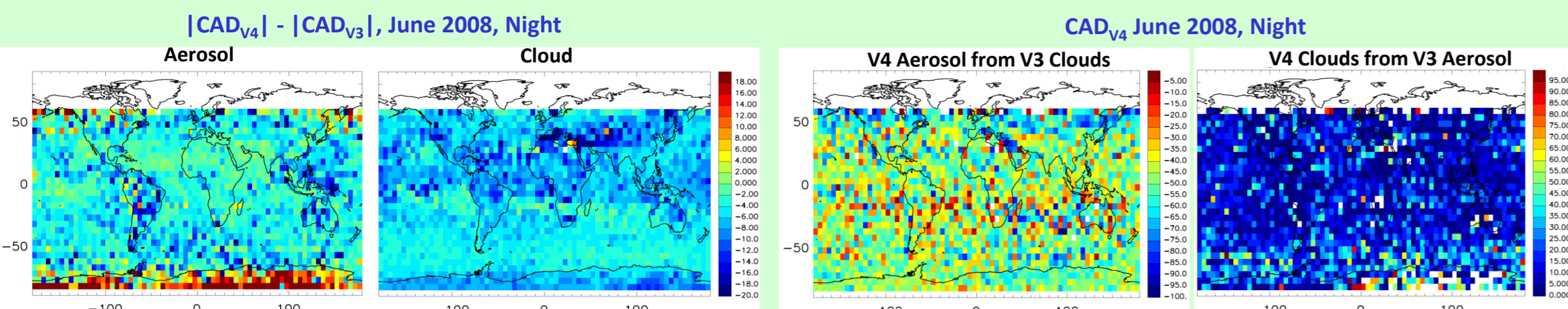
Most layers generally have somewhat lower CAD scores in V4, except the aerosol layers over Antarctica for this month.

Layers which have changed types (aerosol to clouds and vice versa) generally have low CAD score (expected).

	V4 Aerosol	V4 Cloud	V4 Clear
V3 Aerosol	89.5%	5.4%	5.1%
V3 Cloud	4.2%	94.3%	1.5%
V3 Clear	73.1%	26.9%	N/A

Overall confusion matrix for June 2008

A significant fraction of V3 aerosols gets reclassified as V4 clouds in mid to high southern latitudes in June 2008-- consistent with general lack of aerosol sources in these regions.
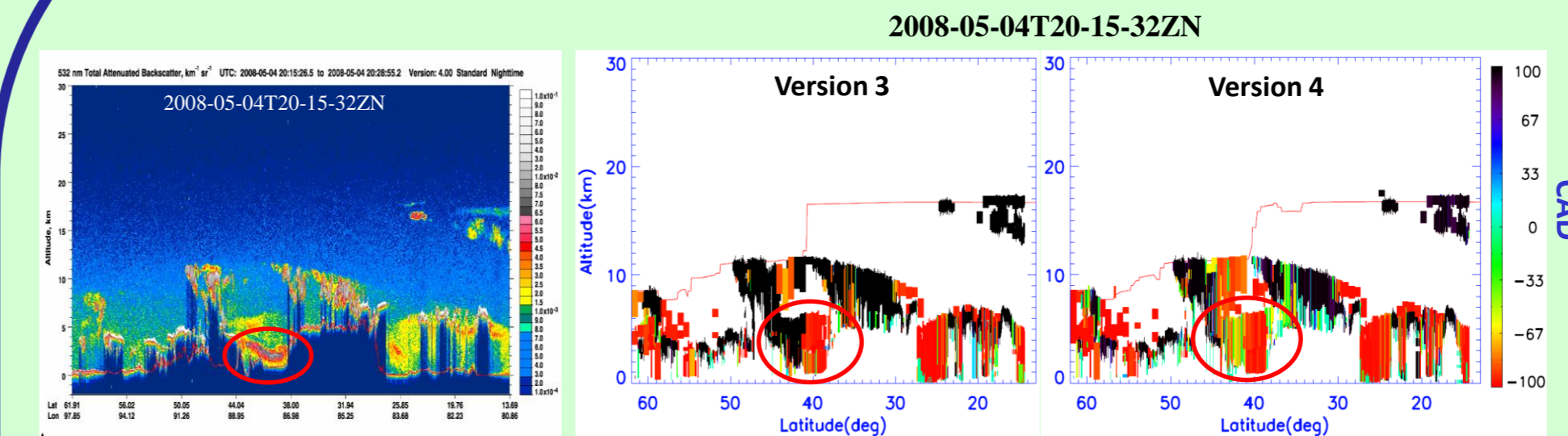
Some clouds in V3 become aerosols in V4 in the northern tropics. A smaller fraction of clouds becomes aerosols at high southern latitudes often having high depolarization and are likely misclassified clouds, as is also suggested by a larger number of cirrus fringes in V4.

CAD PERFORMANCE IN THE TROPOSPHERE

	V4 Aerosol	V4 Cloud	V4 Clear
V3 Aerosol	92.1%	3.5%	4.4%
V3 Cloud	21.1%	78.0%	0.9%
V3 Clear	91.1%	8.9%	N/A

Confusion matrix for Taklamakan Desert region 30°N-45°N, 75°E-90°E, MAM, 2008.

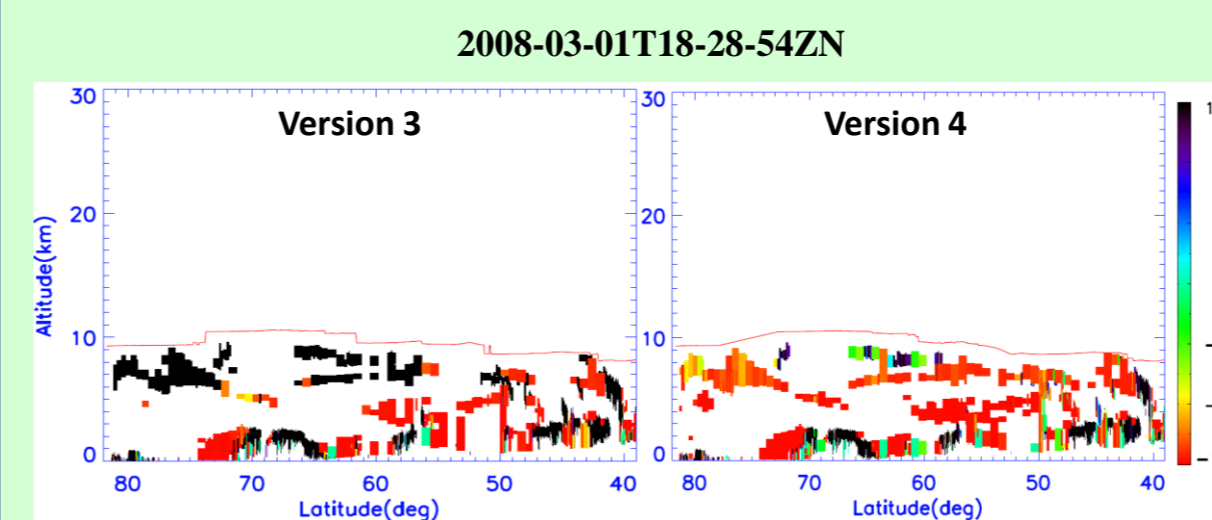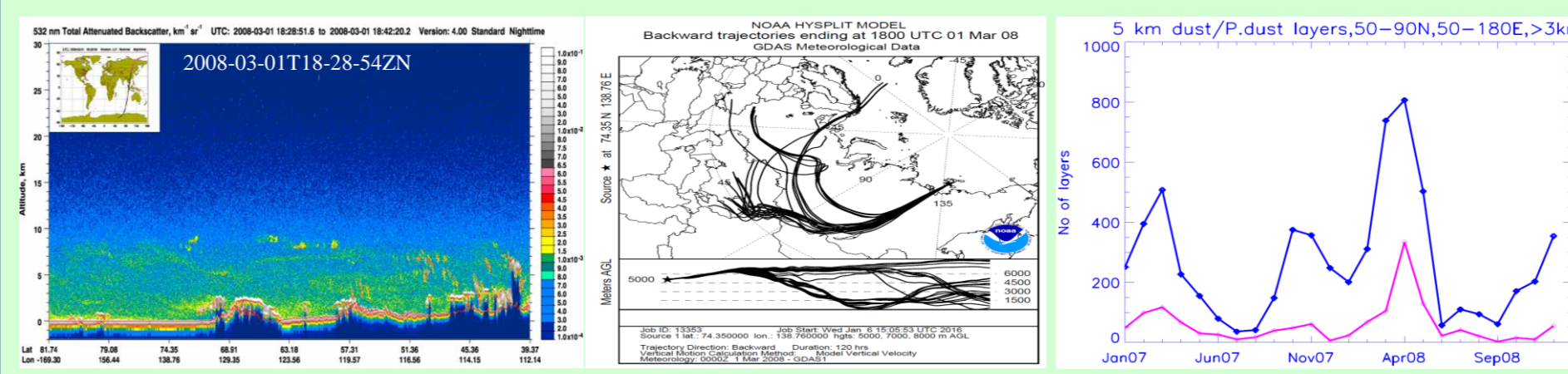|	V4 Aerosol	V4 Cloud	V4 Clear
V3 Aerosol	82.0%	6.8%	11.2%
V3 Cloud	14.1%	84.2%	1.7%
V3 Clear	89.6%	10.4%	N/A

Confusion matrix for 65°N-90°N, MAM, 2008.

★ Improved classification of thick dust layers as aerosols over Taklamakan desert— misclassification of these as clouds were reported in earlier versions (Chen et al., 2010, Jin et al., 2014).

★ Significant improvement in classifying Asian dust and polluted dust layers transported to the Arctic in Spring (clouds in V3). Misclassification reported earlier (Di Pierro et al. 2011) have been mostly resolved.
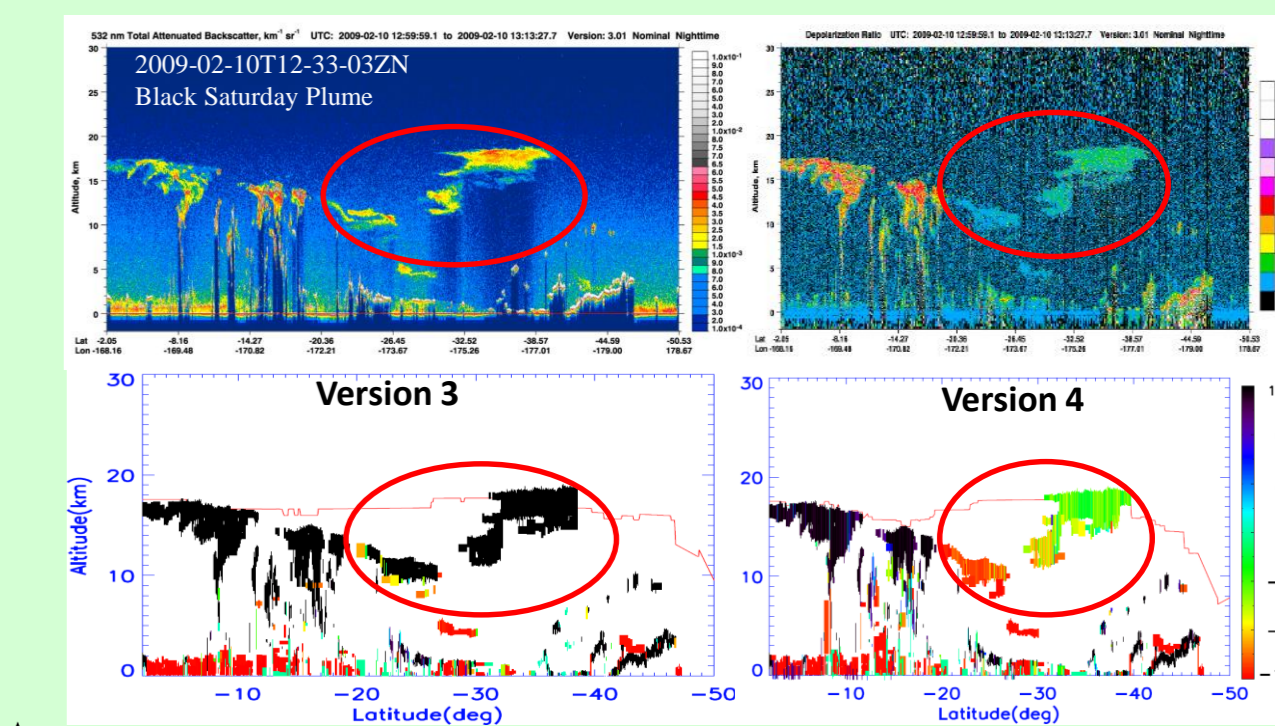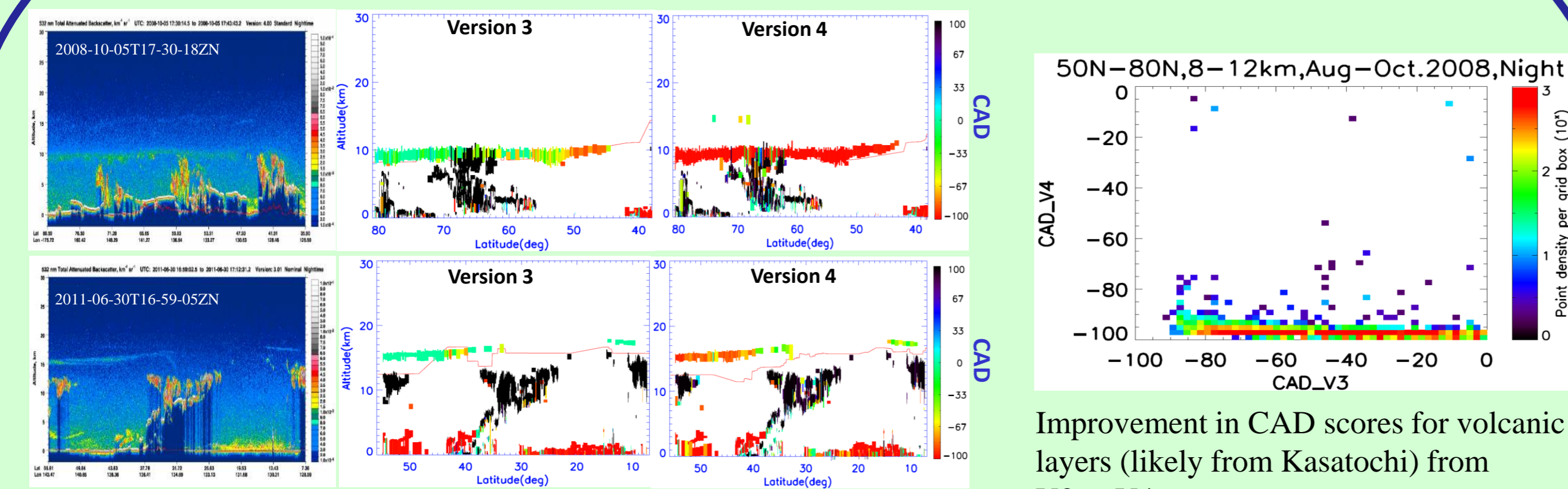
★ Correct classification of high altitude smoke layers as aerosols in V4 rather than clouds in V3. Lower CAD scores for the plume between 30°S-40°S are likely due to the high backscatter and depolarization ratios.
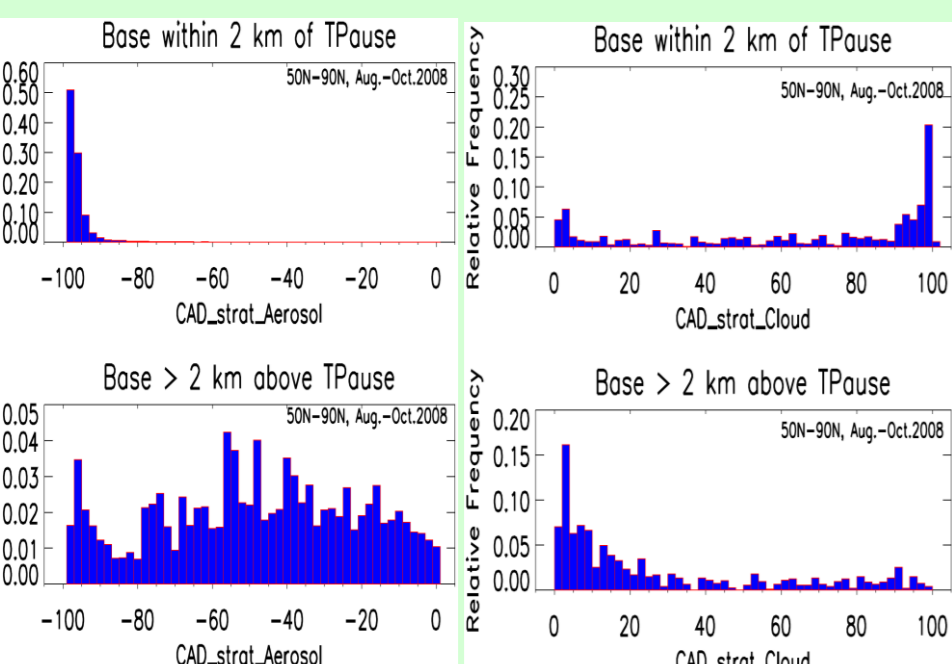
CAD PERFORMANCE IN THE STRATOSPHERE

★ Volcanic layers ("stratospheric features" in V3) are classified as aerosols in V4 CAD. (Top—Kasatochi and bottom—Nabro)

Improvement in CAD scores for volcanic layers (likely from Kasatochi) from V3 to V4.

At very high altitudes, the general lack of samples and falling SNR make CAD increasingly difficult and the PDFs are extrapolated from lower altitudes—most cloud layers have low confidence—consistent with dearth of clouds at stratospheric altitudes.
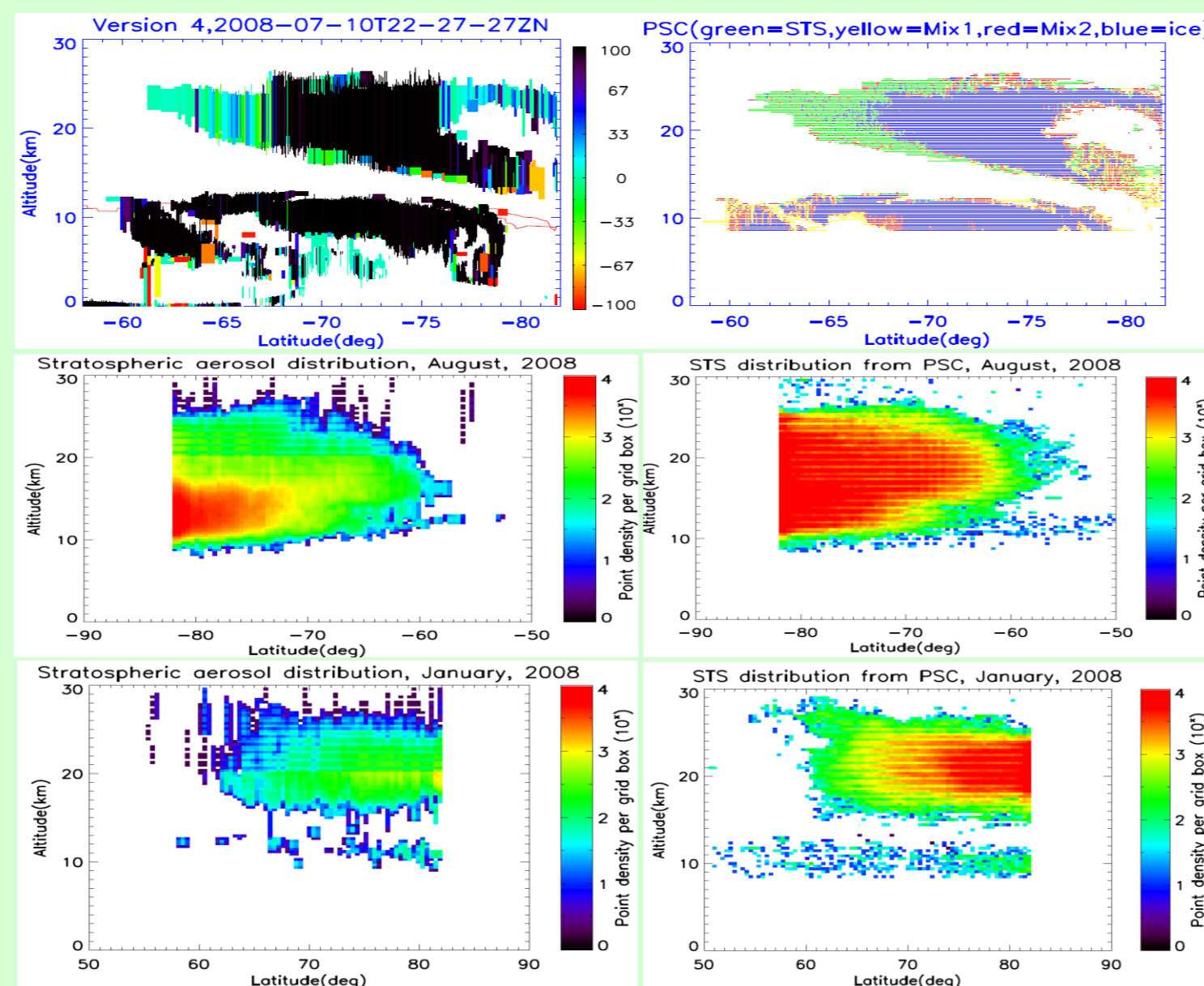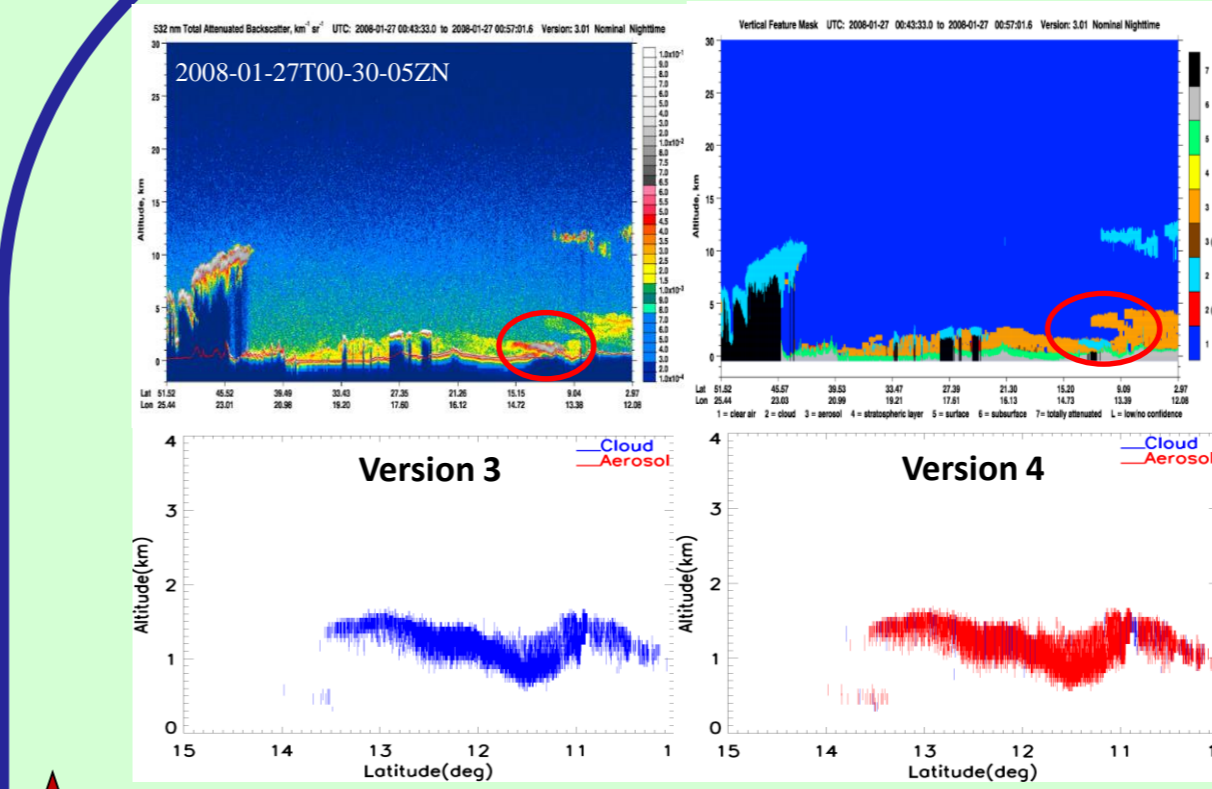
★ VFM from the PSC product compares well with the V4 CAD for PSCs— Supercooled Ternary Solution (STS) is closest to being a liquid aerosol particle and correlates well with aerosol in V4 CAD, albeit with lower CAD. Note that PSC product employs different horizontal averaging and a one-to-one comparison is not possible.
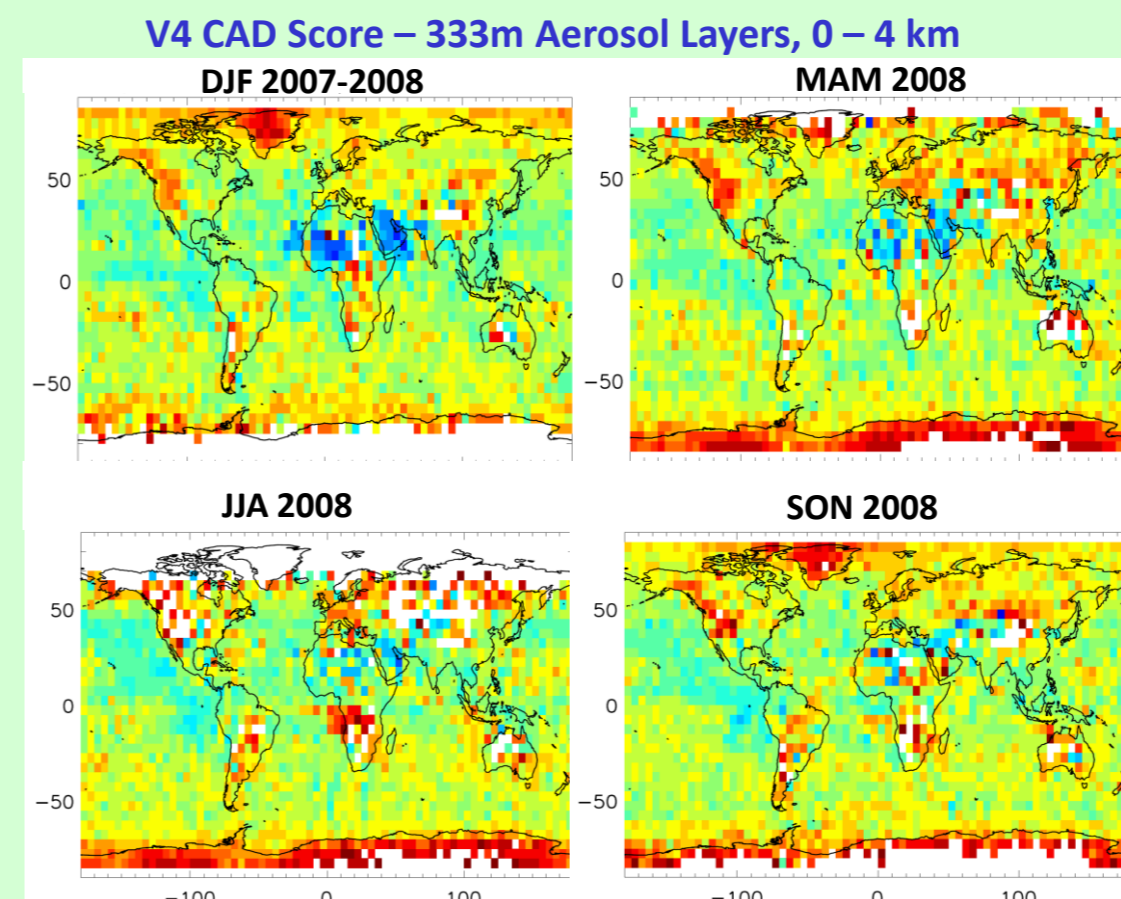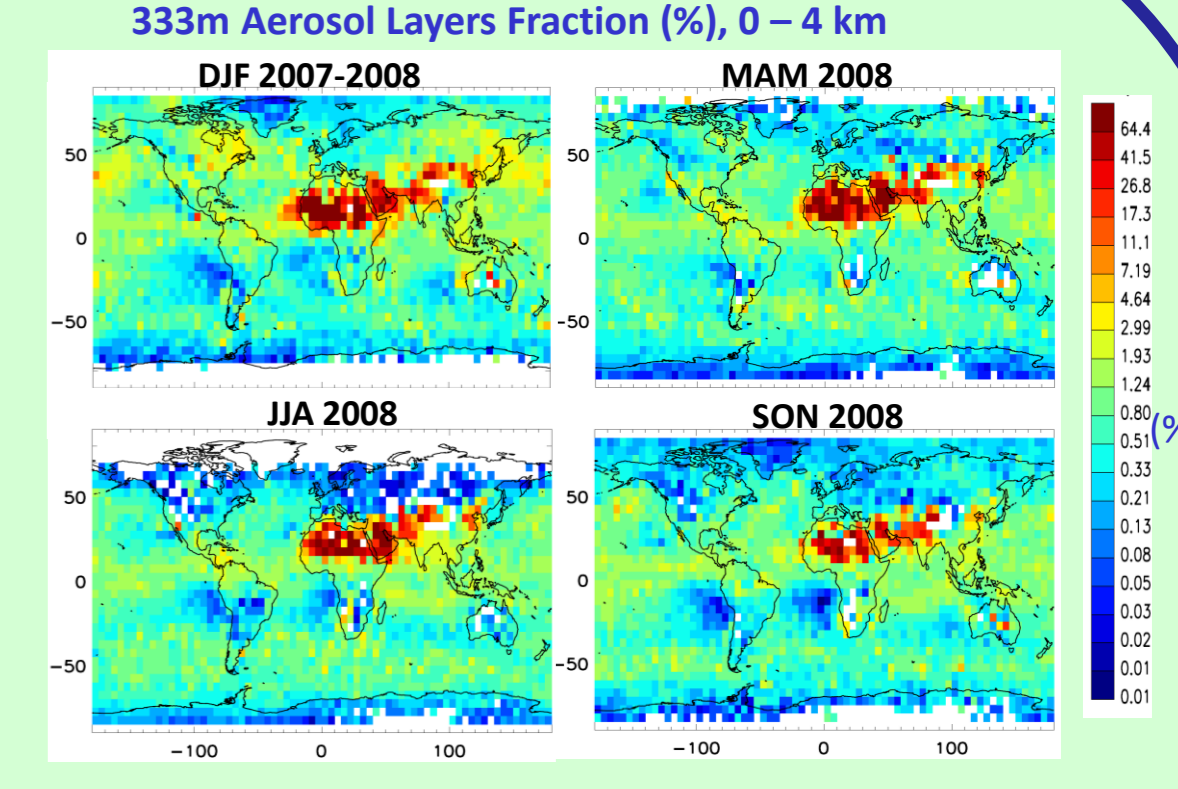
CAD FOR SINGLE SHOT LAYERS (333M)

★ Thick single shot layers often embedded within extended dust or smoke layers classified as clouds in V3 (by default) are now classified as aerosols.

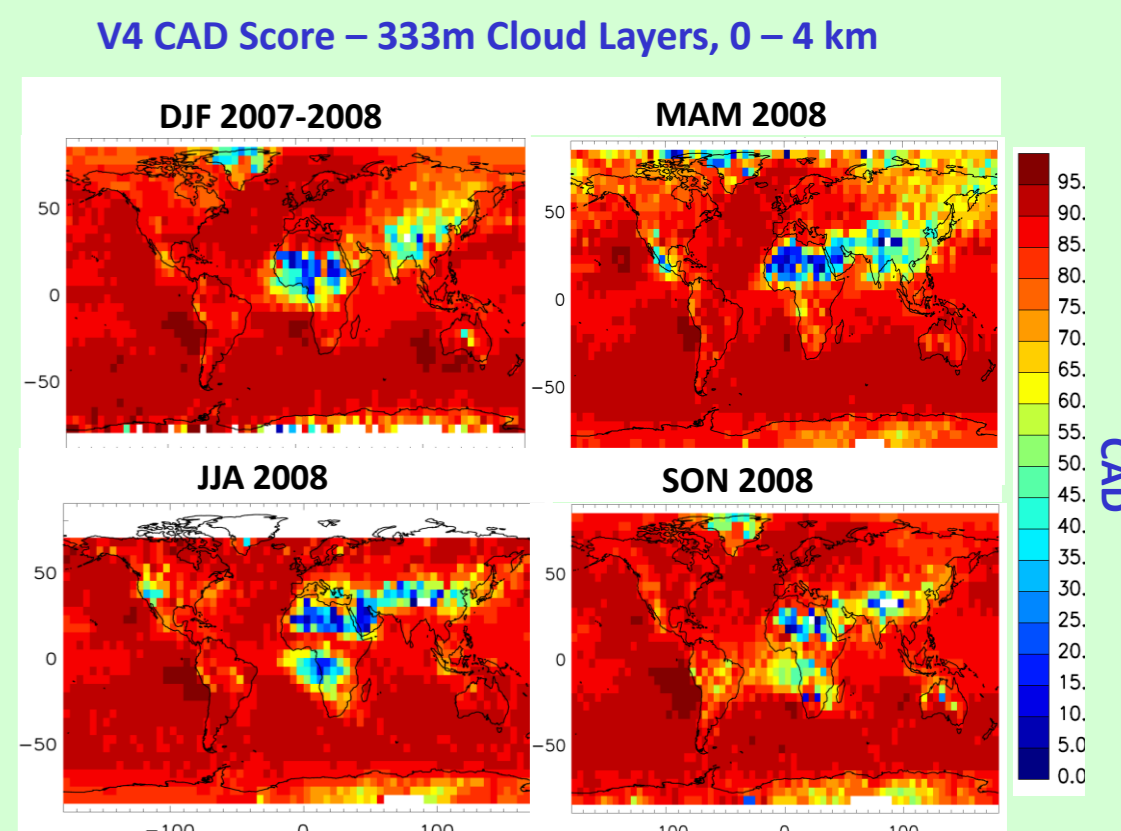Most aerosol layers at 333m show up over the dust belt.

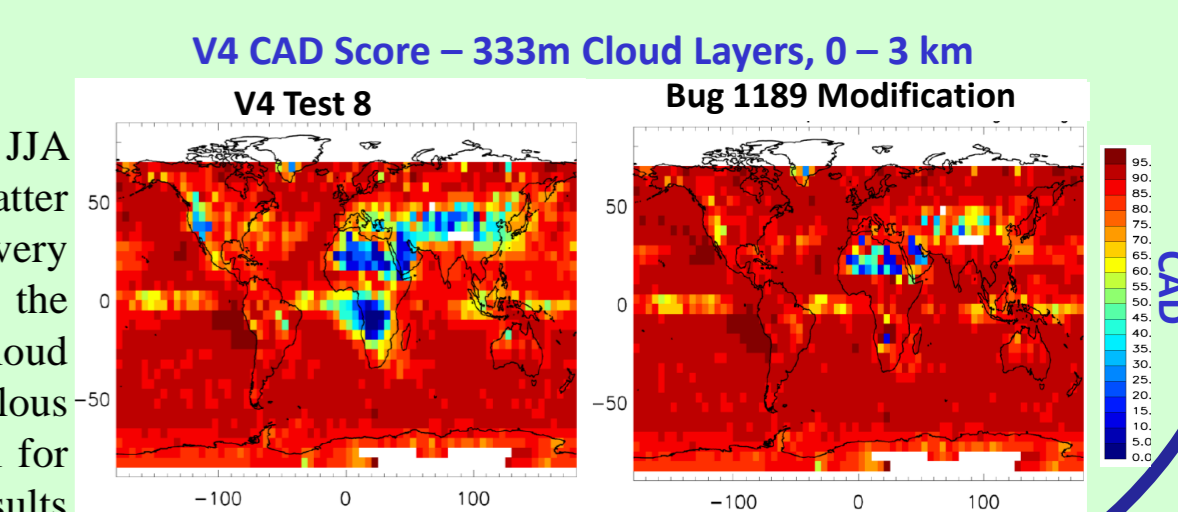CAD scores of 333m layers classified as aerosols are generally highest over the dust belt.

Low CAD scores over the biomass burning areas of Southern Africa in JJA and SON are mostly stratus cloud decks overlain with smoke. The latter attenuates the signal much more at 532 nm than at 1064 nm, leading to very high attenuated color ratios and anomalously low CAD scores for the underlying clouds, even though they may be clearly part of a larger cloud deck with high CAD just outside the smoke plume. For these anomalous cases, the color ratio is reset to the climatological color ratio value of 1.1 for opaque water clouds and then the CAD scores are recalculated. The results are shown in the right panel with the anomaly mostly taken care of.

Most 333m clouds have high CAD scores, except over the dust belt suggesting residual misclassification of thick layers.

References

Chen, B. et al., Detection of dust aerosol by combining CALIPSO active lidar and passive IIR measurements, Atmos. Chem. Phys., 10, 4241-4251, 2010.
Di Pierro, M. et al., Satellite observations of aerosol transport from East Asia to the Arctic: Three case studies, Atmos. Chem. Phys.,11, 2225-2243, 2011.
Jin, Y. et al., Improvement of CALIOP cloud masking algorithms for better estimation of dust extinction profiles, J. Meteorol. Soc., 92, 433-455, 2014.
Liu, Z et al., The CALIPSO lidar cloud and aerosol discrimination: Version 2 algorithm and initial assessment of performance, JAOT, 26, 1198-1213, 2009.
Vaughan, M. et al., Fully automated detection of cloud and aerosol layers in the CALIPSO lidar measurements, JAOT, 26, 2034-2050, 2009.

Contact: jayanta.kar@nasa.gov

Conclusions:

- **V4 CAD has made significant improvements in the troposphere, including classification of thick layers over Taklamakan desert and transported layers from Asia in spring over Arctic.**
- **In the stratosphere, volcanic layers and STS layers in the PSC regime are being correctly classified.**
- **V4 CAD has been successful in classifying the thick single shot (333m) aerosol layers embedded within extended dust plumes.**